

The lost digit - Buk 3x2

A Bellingcat Investigation

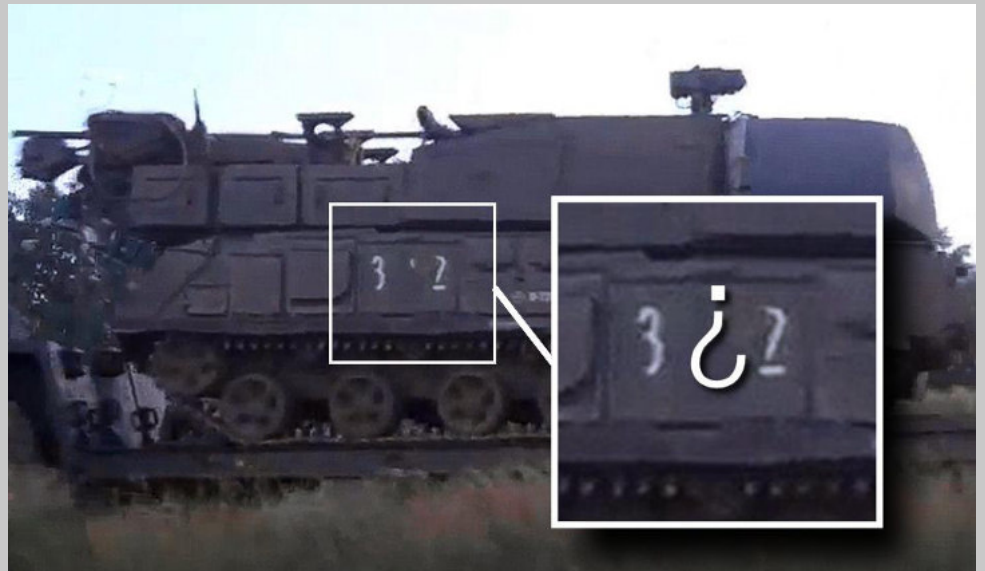


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Introduction

In the report "Origin of the Separatists' Buk",¹ the Bellingcat team was able to determine that a Buk-M1 TELAR (missile launcher) was under control of the pro-Russian separatists in eastern Ukraine on 17 July 2014. It could be established that this Buk photographed in eastern Ukraine on 17 July is identical to a Buk missile launcher transported in June 2014 by the 53rd Anti-Aircraft Missile Brigade of the Russian army, based in Kursk.



"Paris Match" -Photo

June Convoy Buk 3x2

This specific Buk² from Kursk was marked with a "3", an obscured number in the middle, and a "2" at the end – and was therefore named Buk 3x2. There has been much speculation about the missing digit in the middle. This report will attempt to conclusively identify the world's most infamous Buk by determining its missing middle digit.



The missing digit

This report is organized into four sections. Section one provides information on which Buk missile launchers are considered and also basic information about the Buk air defense system. In the second section, a systematic comparison of individual feature of Buk 3x2 and selected Buks of the 53rd Anti-Aircraft Missile Brigade is presented. The existence of the same features on the Buk recorded in eastern Ukraine is examined in section three. The final section of this report concludes with a broader consideration and a brief discussion of the result.

¹ <https://www.bellingcat.com/news/uk-and-europe/2014/11/08/origin-of-the-separatists-buk-a-bellingcat-investigation/>

² Hereafter, the term "Buk" will also be used as an abbreviation for Buk TELAR. If the complete system is meant, it is explicitly stated.

Limiting the Possibilities

With the first and the last digit available, only one digit is missing. When this digit is determined, the number of Buk 3x2 could be reconstructed. Therefore, the main question is: Which digits are possible? Mathematically, all from "0" to "9". In reality, even fewer digits are plausible.

Vehicles of the 53rd Anti-Aircraft Missile Brigade

However, even if the missing digit is determined, we must identify the military formation that the Buk belongs to in order to clearly identify the right vehicle. The reason is that the visible number on a Buk is not unique within the entire army. The Russian military has multiple Anti-Aircraft Missile Brigades and theoretically, each brigade could have a Buk with the identified number. Another approach was used in order to not check every Buk in the Russian military.

The November 2014 Bellingcat report "Origin of the Separatists' Buk"³ documents how Buk 3x2 was in June 2014 part of a convoy mainly formed by vehicles from the 2nd battalion of the 53rd Anti-Aircraft Missile Brigade from Kursk. Furthermore, an investigation into the individual soldiers showed that soldiers of the 2nd battalion participated in this convoy.⁴ Because of the clear link between the 53rd Anti-Aircraft Missile Brigade and the June 2014 convoy which transported Buk 3x2 from Kursk to the Russian-Ukrainian border, Buks of the 53d Anti-Aircraft Missile Brigade are the primary candidates for Buk 3x2.

Therefore, only vehicles in, or connected to, the 53rd Anti-Aircraft Missile Brigade are considered and compared in this investigation. Firstly, all Buks of the 53rd Anti-Aircraft Missile Brigade were considered as possible candidates. However, the investigation revealed that some Buks could be excluded because of specific features or their presence in a July 53rd Anti-Aircraft Missile Brigade convoy to the Russian-Ukrainian border area in summer 2014. Furthermore, the visible digits "3" and "2" provide important identifying information.

Numbering of the vehicles in the structure of the 53rd Anti-Aircraft Missile Brigade

The manufacturer⁵ supplies the Buk-M1 and the newer Buk-M1-2 system with the following components:^{6 7}



Command vehicle 9S470



Radar vehicle 9S18 Kupol

³ <https://www.bellingcat.com/news/uk-and-europe/2014/11/08/origin-of-the-separatists-buk-a-bellingcat-investigation/>

⁴ <https://www.bellingcat.com/news/uk-and-europe/2016/02/23/53rd-report-en/>

⁵ <http://www.webcitation.org/6GqJZC2Vq>

⁶ http://rbase.new-factoria.ru/missile/wobb/bukm1_2/bukm1_2.shtml

⁷ <http://rbase.new-factoria.ru/missile/wobb/buk/buk.shtml>



TELAR with radar 9A310



TEL with crane 9A39

Both missile launchers in the modification M1 can fire missiles of type 9M38⁸ or 9M38M1⁹, and with the M1-2 modification can fire missiles of type 9M38M1¹⁰ or 9M317¹¹. A typical Buk-M1 system is composed of (excluding training vehicles / equipment):

- One Command vehicle 9S470
- Six TELAR with radar 9A310 (TELAR = transporter erector launcher and radar)
- Three TEL with crane 9A39 (TEL = transporter erector launcher)
- One Radar vehicle 9S18 Kupol (TAR = target acquisition radar)
- Additional support vehicles (see Appendix A)

The 53rd Brigade closely follows this structure.¹² The brigade itself is divided into battalions, and the battalions into batteries. By the end of 2013, the 53rd Brigade had three Buk battalions. A battalion is composed of a complete Buk-M1 system with 1 command vehicle, 1 radar vehicle, 6 missile launchers with radar (TELAR), 3 missile launchers with cranes (TEL) as well as the aforementioned support vehicles. The missile launchers of the Buk-M1 system in a battalion are divided into three batteries. Each battery has two TELAR 9A310M1(-2) and one TEL 9A39M1. However, the brigade allows a flexible assignment of the batteries to a Buk-M1 system. (see Appendix B). An analysis of open source materials shows that the numbers visible on the Buk are defined according to the structure of the unit and are best described as unit designation number. The first digit indicates the battalion, the second digit the battery in the battalion, and the third digit the position in the battery. The second and third digits of command vehicles are "00", radar vehicles have "01," TELAR have "1" or "2" as the third digit, and TEL vehicles use "3" as the third digit.¹³

Thus, below is an overview of the applicable numbers for Russia's 53rd Anti-Aircraft Missile Brigade:

53rd Anti-Aircraft Missile Brigade			1. Battery			2. Battery			3. Battery		
	Command 9S470M1	Radar 9S18M1	TELAR 9A310M1	TELAR 9A310M1	TEL 9A39M1	TELAR 9A310M1	TELAR 9A310M1	TEL 9A39M1	TELAR 9A310M1	TELAR 9A310M1	TEL 9A39M1
1. Battalion	100	101	111	112	113	121	122	123	131	132	133
2. Battalion	200	201	211	212	213	221	222	223	231	232	233
3. Battalion	300	301	311	312	313	321	322	323	331	332	333

Table - Numbering of vehicles in the 53rd Anti-Aircraft Missile Brigade¹⁴

⁸ <http://rbase.new-factoria.ru/missile/wobb/buk/buk.shtml>

⁹ <http://rbase.new-factoria.ru/missile/wobb/buk/buk.shtml>

¹⁰ http://www.niip.ru/index.php?option=com_content&view=article&id=16:-1-2r&catid=9:2011-07-06-06-33-50&Itemid=9

¹¹ <http://rbase.new-factoria.ru/missile/wobb/buk-2m/buk-2m.shtml>

¹² <https://www.bellingcat.com/news/uk-and-europe/2016/02/23/53rd-report-en/>

¹³ <https://www.youtube.com/watch?v=ZvkC4tZNisg>

¹⁴ <https://www.bellingcat.com/news/uk-and-europe/2016/02/23/53rd-report-en/>

In the convoy that went from Kursk to Millerovo on 24-26 June 2014, the following numbers were visible in available videos:

53 rd Anti-Aircraft Missile Brigade	1. Battery			2. Battery			3. Battery				
	Command	Radar	TELAR	TELAR	TEL	TELAR	TELAR	TEL	TELAR	TELAR	TEL
	9S470M1	9S18M1	9A310M1	9A310M1	9A39M1	9A310M1	9A310M1	9A39M1	9A310M1	9A310M1	9A39M1
June convoy	200	201	211	212	x23	221	3x2	223	231	232	xxx

On three vehicles, the numbers were not completely legible:

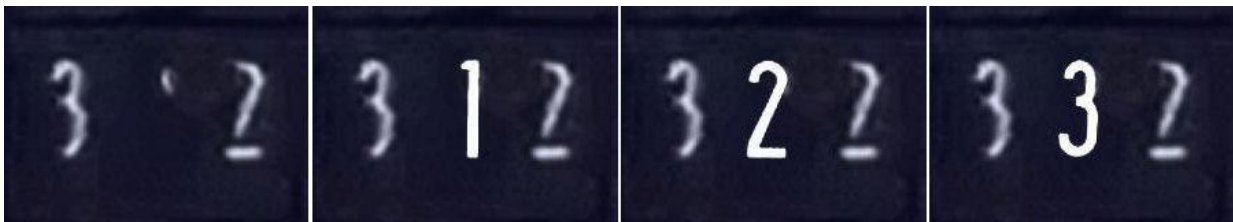
The table above only shows vehicles that clearly belonged to the 2nd battalion. It is noticeable that three vehicles are seemingly missing. These vehicles of the 2nd battalion were replaced by:

- a TEL without a number
- a TEL with the number x23
- a TELAR with the number 3x2

With these three vehicles, all of which had indefinite numbers, the Buk-M1 system in the June convoy was complete.

There is no evidence documenting the involvement of the 1st battalion in the June convoy¹⁵. Therefore, it can be concluded that the TEL vehicles with indefinite numbers must be from the 2nd or the 3rd battalions. However, the identification of both TELs is not within the scope of this report. Moreover, the numbers of these TEL vehicles is not nearly as important as determining the middle digit of the TELAR with the number 3x2.

Because of the above presented considerations, the search for the missing digit of TELAR 3x2 can be limited to the following three options: "1", "2" or "3". The unit designation number lacks the digit indicating the battery in the 3rd battalion. The visible part of the missing digit could therefore be a fragment of one of the three options: "1", "2" or "3". Unfortunately, the fragment is not large enough, as seen in the comparison below, to reach a conclusion. Each possible number hides the crucial middle fragment.



Review of the paint remains of the missing digit

¹⁵ Buk 3x2 was part of a convoy in June 2014, a second Buk convoy from the 53rd Anti-Aircraft Missile Brigade was filmed after 17.07.2014, for details, see <https://www.bellingcat.com/news/uk-and-europe/2016/02/23/53rd-report-en/>

Comparison of Buk 3x2 with Buks 312, 322 and 332

The considerations presented in the last section reduce the potential candidates to only Buk 312, 322 and 332 of the 53rd Anti-Aircraft Missile Brigade. However, it is not possible to conclusively identify the specific Buk with only the remaining paint fragment from the middle digit. Therefore, the following section will present and compare the individual features of Buk 3x2 with these three Buks.

Comparison of side skirts fingerprints

A survey of available social media materials revealed that various VKontakte (VK) accounts have photographs of TELARs from the 3rd battalion of the 53rd Anti-Aircraft Missile Brigade. Some of the images are suitable for a side skirt comparison with the side skirt fingerprint method. Images are available from 2009 to 2013. Unfortunately, more current photographs are not available. Nevertheless, it could still be possible to identify TELAR 3x2 from the side skirt profiles from this survey of available photographs.



Buk 312 (Original photo)¹⁶



Buk 322 (Original photo)¹⁷



Buk 332 (Original photo)¹⁸



Buk 312 - detail



Buk 322 - detail



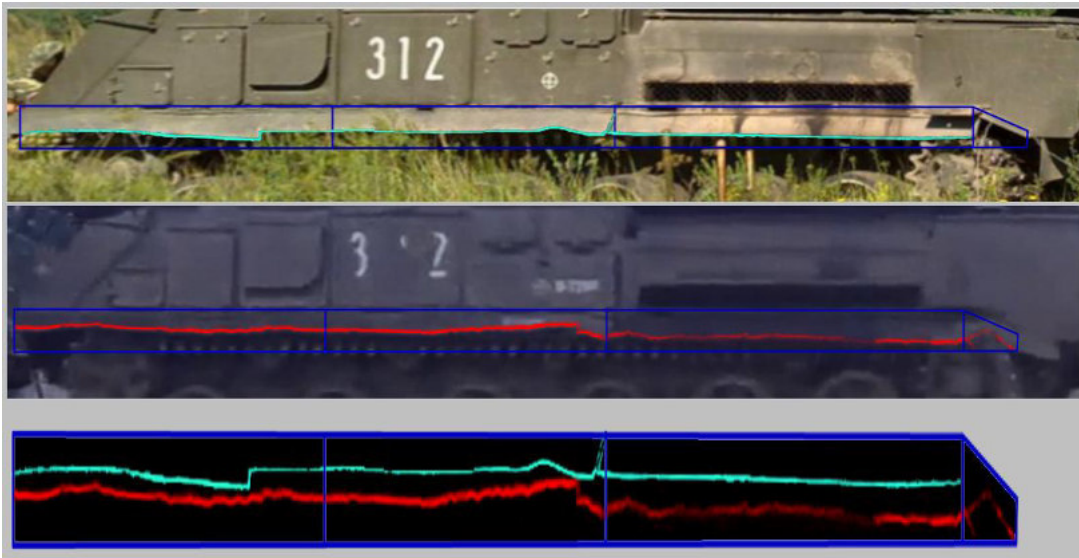
Buk 332 - detail

Below are the three comparisons for each of the three Buks. It can be seen that each Buk has its own distinctive features and side skirt profile. The direct comparison reveals that none of the three Buks can be conclusively identified as 3x2 by only using this methodology. For each Buk, there are visible differences in the visible "wave form."

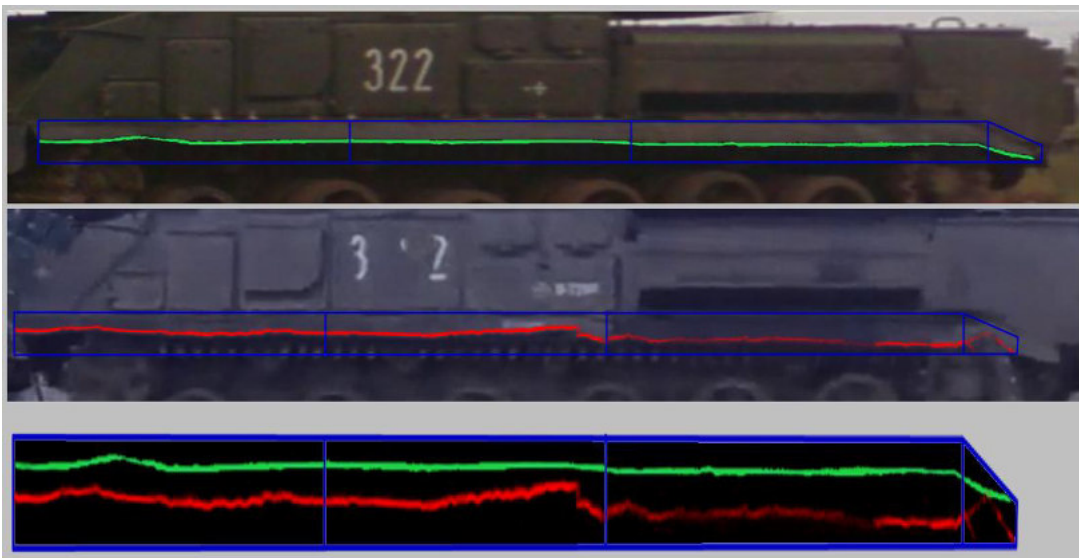
¹⁶ http://vk.com/photo-56400949_306455856 Archived - <https://archive.today/cbccx>

¹⁷ http://vk.com/photo34843743_336984208 Archived - <https://archive.today/vmeFR>

¹⁸ <https://archive.today/tzDIP>



"Fingerprint" comparison between Buk 312 and Buk 3x2



"Fingerprint" comparison between Buk 322 and Buk 3x2



"Fingerprint" comparison between Buk 332 and Buk 3x2

Obviously, the expectable similarity of the side skirt fingerprint depends on the passed time between the used materials for the comparison. The reason for the decreasing likelihood of an identical side skirt fingerprint is that the likelihood of an event affecting the visible wave form will be higher if more time passed. A repair of damaged parts or new damage occurred in exercises are two potential and obvious causes for an observed different wave form. Therefore, while it is possible that a certain wave form is visible for some years, this cannot necessarily be expected in all cases.

In case of Buk 332 it is known that after 2010, the year the reference photo for the comparison was taken, its side skirt was severely damaged.¹⁹ The damaged parts were most likely replaced. Since no comparison photo is available for the "fingerprint" after these repairs, the non-result of the side skirt comparison is obviously inconclusive for this Buk. A similar clear reason that might have affected the side skirt is not documented by the available material for Buk 312 and 322. However, because of the inconclusive result of this comparison due to a lack of more current imagery, other features of Buk 3x2 are considered in the next subsection.

Other Special Features of Buk 3x2

The Buk 3x2 that was part of the June convoy has at least six additional notable features that allow a more accurate comparison with the three Bucs (312, 322 and 332) from the 53rd Anti-Aircraft Missile Brigade. None of these features alone is conclusive enough to allow a clear identification. However, the combination of all these uncommon features together form a unique set of characteristics and can be considered suitable for a positive identification.



Individual features of Buk 3x2 – Details of video and photos^{20 21 22}

The six examined features are:

- A: wheel type (combination of hollow wheels and spoke wheels)
- B: dent in the left side panel
- C: arrangement of cable connections to the missile erector
- D: white mark on both side skirts
- E: font and exact spacing of digits
- F: shape and size of oil/soot deposits by exhaust

¹⁹ http://vk.com/photo6517055_286122407 Archived - <https://archive.is/EhTcl>

²⁰ <https://youtu.be/dO8cBm2kqps>

²¹ http://vk.com/wall-62387983_26806 Archived - <https://archive.is/bPiSs>

²² <https://youtu.be/c4Pigqg8A74>

A: Shape and arrangement of road wheels

The chassis GM 569A^{23 24} used for a Buk TELAR has 6 road wheels on each side. There are two clearly different types of road wheels for the GM 569A chassis.²⁵



Spoke wheel



Hollow wheel

The total weight of max. 32.4t²⁶ of a Buk TELAR is spread over these 12 road wheels. As seen in available videos and photographs, after some time, a single wheel is often replaced. The reason for this is unclear—possibly because of the massive load, a particular design fault, or a different unknown reason. If the replacement road wheels have a different type than the standard wheel of the Buk, the specific order of the different wheels forms a profile.

The available materials of Buk 3x2 show that it has both wheel types. The type of the last wheel on the right side is unknown. The wheels have the following arrangement:



Buk 3x2 road wheels, right side²⁷



Buk 3x2 road wheels, left side²⁸

It is noticeable that Buk 3x2 has almost exclusively spoked wheels; however, at least one wheel is hollow.²⁹ This hollow wheel is located on the right at the second position from the left. It is not possible to identify the type of the last wheel on the right side.

²³ <http://vpk.name/library/f/gm-569.html>

²⁴ http://www.militaryparitet.com/nomen/russia/spmachine/sgm/data/ic_nomenrussiaspmachinesgm/12/

²⁵ For the purpose of this report, these two types of wheels will be called spoke and hollow wheels. The spoke wheel has five radial reinforcing ribs, and the hollow wheel is axially symmetrical without ribs.

²⁶ <http://rbase.new-factoria.ru/missile/wobb/buk/buk.shtml>

²⁷ <https://youtu.be/dO8cBm2kqps>

²⁸ <https://youtu.be/c4Pigqq8A74>

Buk 312 has exclusively hollow wheels. The exact arrangement and type of wheels for Buk 312 can be seen below:



Buk 312 road wheels, right side ³⁰



Buk 312 road wheels, left side ³¹

Buk 322 has exclusively spoked wheels. The arrangement and type of road wheels for Buk 322 can be seen below:



Buk 322 road wheels, right side ³²



Buk 322 road wheels, left side ³³

Buk 332 has exclusively spoked wheels except for a wheel on the right side. The roller on the second position on the right side is a hollow wheel. The arrangement and type of wheels for Buk 332 can be seen below:

²⁹ <http://flight-mh17.livejournal.com/156025.html?thread=2628473#t2628473>
³⁰ <http://ok.ru/voyskovoep/album/57067294621747/593420957491> Archived - <http://archive.is/e3jFO>
³¹ http://vk.com/photo-56400949_306455754 Archived - <http://archive.is/WwBBw>
³² https://vk.com/photo17027917_306001423 Archived - <http://archive.is/dW7lX>
³³ http://vk.com/photo34843743_336984208 Archived - <http://archive.is/vmeFR>



Buk 332 road wheels, right side^{34 35}



Buk 332 road wheels, left side³⁶

This comparison shows that Buk 312 can be excluded, since it has only hollow wheels. It seems implausible that 11 wheels were replaced before June 2014. Buk 322 has only spoke wheels and missed the hollow wheel on the right side. Buk 332, however, has the exact same visible wheel profile as 3x2: all spoked wheels, except for the second wheel on the right side being hollow.

B: Dent in the side panel

On a photo of Buk 3x2 taken near Alexeevka, Russia, an inverted S-shaped dent is visible on the left side panel. Below is an image from the June convoy and a highlighting of the damage. Only the lower part of the side panel is damaged with a quite specific shape, making this damage suitable for a comparison.



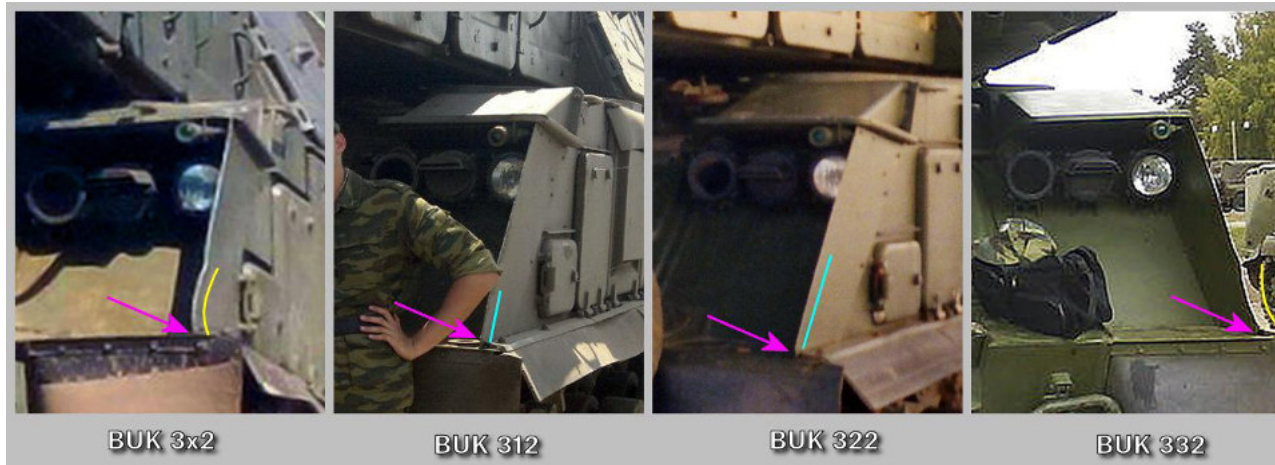
Buk 3x2 – Dent in the side panel³⁷

³⁴ <http://ok.ru/voyskovoep/album/57067294621747/593317387827> Archived - <http://archive.is/M4NcH>

³⁵ See also <http://archive.is/6yGLv>

³⁶ <http://ok.ru/voyskovoep/album/57067294621747/593332501299> Archived - <http://archive.is/tgdZw>

The figure below shows the side plate of Buk 3x2 and of BUKs 312, 322 and 332 of the 53rd Anti-Aircraft Missile Brigade:



Compare - Dent in the side panel - Details of photos^{38 39 40 41}

The comparison clearly shows that only the side panel of Buk 332 shows the same type of damage. The damaged area of the side panel appears near identical compared to Buk 3x2.

C: Cables connected to the missile erector

On the revolving turret of the Buk is a cable connection, where on each side there are four cables leading to the missile erector. In total, there are eight cables which can be compared.



Buk 3x2 - Cables connection to the missile erector - Details of photo⁴²

Various BUKs show different arrangements and different lengths of this cable connection. In the following two figures, the cable connection of Buk 3x2 is compared to the ones of BUKs 312, 322 and 332.

³⁷ http://vk.com/wall-62387983_26806 Archived - <https://archive.is/bPiSs>

³⁸ http://vk.com/wall-62387983_26806 Archived - <https://archive.is/bPiSs>

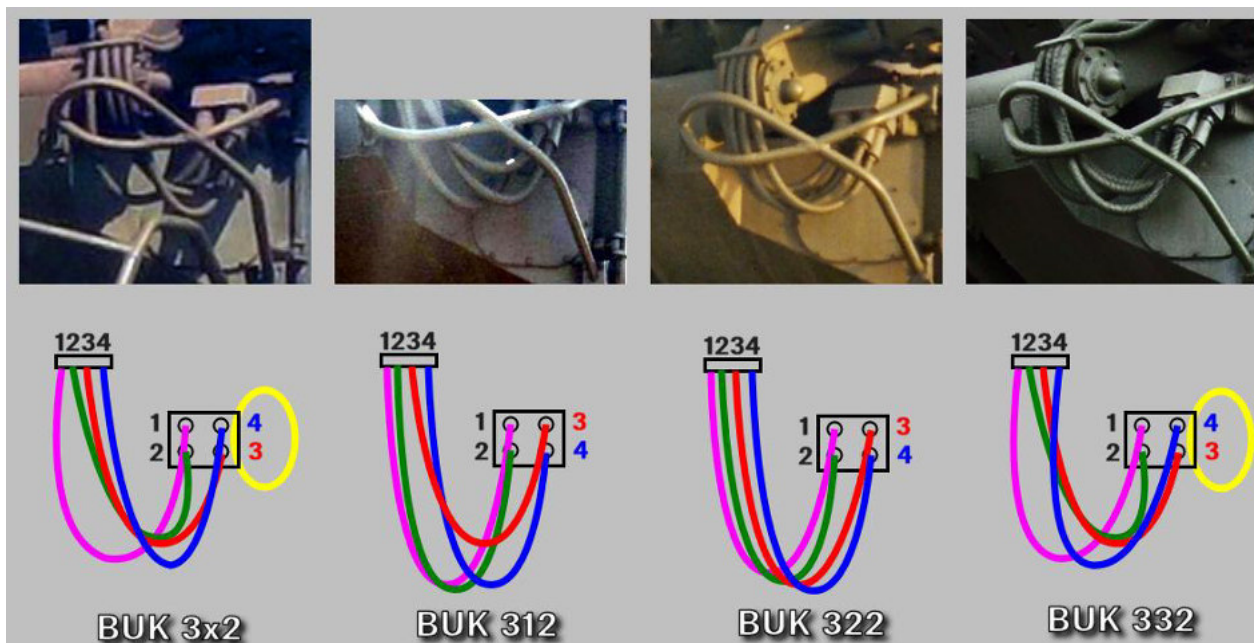
³⁹ <http://savepic.ru/9471615.jpg>; <http://savepic.ru/9453182.jpg>

⁴⁰ http://vk.com/photo6200217_272542369 Archived - <http://archive.is/YwhFL>

⁴¹ <http://ok.ru/voyskovoep/album/57067294621747/593316899379> Archived - <http://archive.is/Vmyl3>

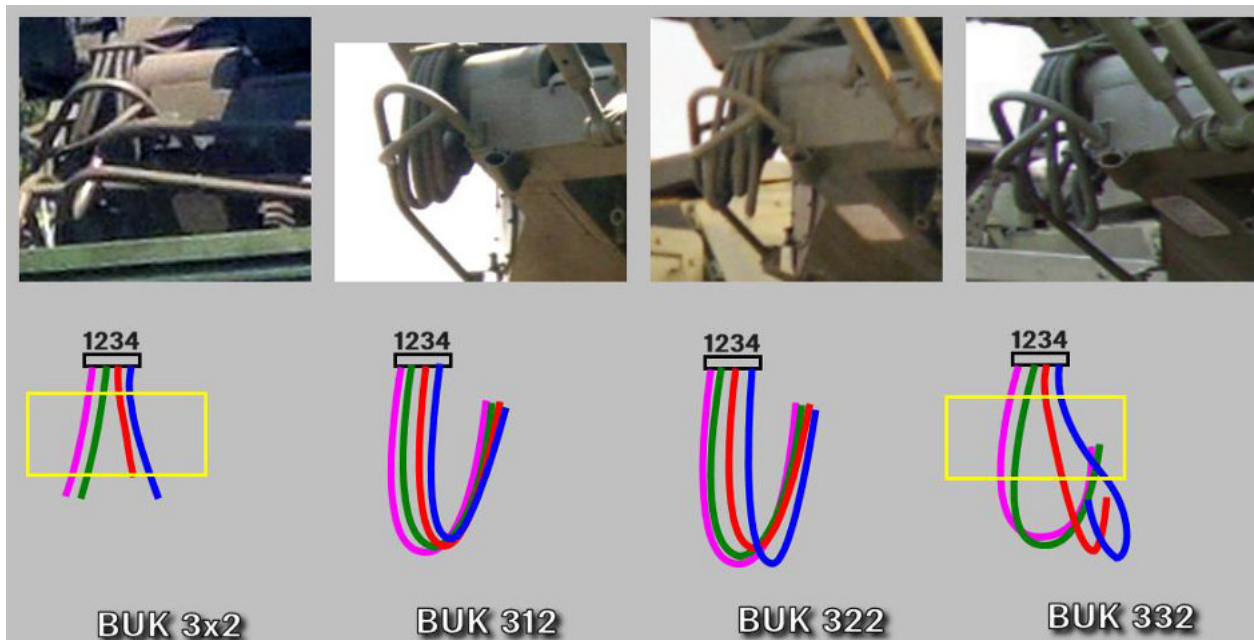
⁴² https://vk.com/wall-62387983_26806 Archived - <http://archive.is/bPiSs>

The cables connection of the right side is presented below:



Buks 3x2, 312, 322 and 332 - cable connection on the right side - Details of photos ^{43 44 45 46}

Only Buk 332 has similarities with Buk 3x2's cables and connections. The blue-marked cable four is connected to the top plug on the turret chassis. Buk 312 and 322 show a different cabling, and cable four is connected to the bottom plug. Also, Buk 312, 322 and 332 show a distinct shape of the cabling, and only the shape of Buk 332 resembles that of the cabling of 3x2. The figure below shows the cables connection on the left side:



Buks 3x2, 312, 322 and 332 - cable connection on the left side - Details of photos ^{47 48 49}

⁴³ https://vk.com/wall-62387983_26806 Archived - <http://archive.is/bPiSs>

⁴⁴ <http://savepic.ru/9471615.jpg>; <http://savepic.ru/9453182.jpg>

⁴⁵ http://vk.com/photo6200217_272542369 Archived - <http://archive.is/YwhFL>

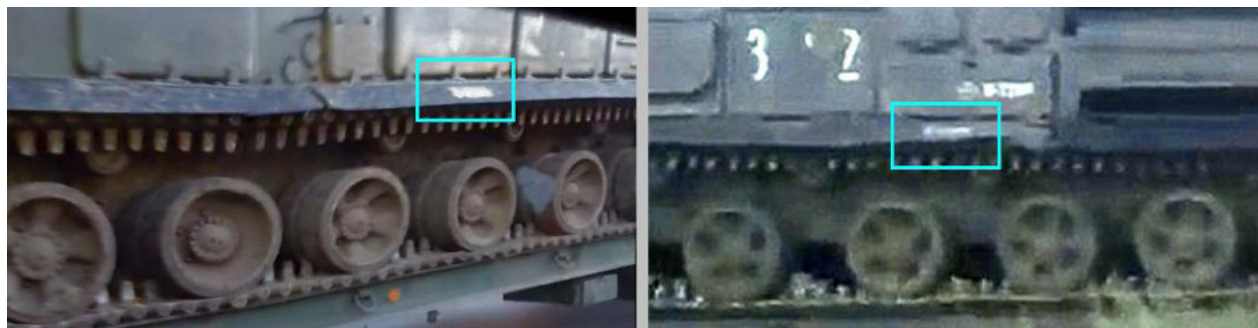
⁴⁶ <http://ok.ru/group/52790918643940/album/53063513211108/562212661220> Archived - <https://archive.is/yOr9m>

The comparison on the left side allows only a partial comparison. It is not possible to see the plugs on the turret chassis. However, Buk 332 shows the same distinct spread of the cabling in the middle that is also visible on 3x2. Nothing comparable is visible on 312 or 322.

In sum, neither Buk 312 nor 322 have a cabling comparable to 3x2, and only the cabling of Buk 332 strongly resembles that of Buk 3x2 on both sides.

D: White marks on side skirts

In the imagery available for Buk 3x2, white marks are visible on both side skirts directly below the center of gravity mark. Presumably, the white mark is the inscription "H-2200", a railroad transport code for dimensions of oversized cargo. Only Buk 3x2 had such a mark on the side skirts in the June convoy. Thus, in this convoy, the white mark on both side skirts is a unique feature of Buk 3x2.



Buk 3x2 - White marks on both sides of Buk - Details of videos^{50 51}

The reviewed photos of 53rd Anti-Aircraft Missile Brigade do not show this label on this position on Buk 312, 322 or 332. However, considering that this mark is added specifically before railway transport, the mark was likely added after the last available reference photo. Available photographs document that this position for the "H-2200" mark on the side skirt is used by the 53rd Anti-Aircraft Missile Brigade.

E: Font and spacing of digits

The available materials of these Buks of the 53rd Anti-Aircraft Missile Brigade show that the digits used in year 2010 and 2014 have a different font. The vehicles were repainted once between 2010 and 2014, likely in the first half of 2012.



Fonts and spacing of the numbering of the Buks in the 53rd Anti-Aircraft Missile Brigade

In 2012, Buk 312, 322 and 332 used the same font. A notable difference between the Buks is the larger spacing of the digits that is unique for Buk 332. A comparison between 3x2 and

⁴⁷ https://vk.com/wall-62387983_26806 Archived - <http://archive.is/bPiSs>

⁴⁸ http://vk.com/photo6200217_272542369 Archived - <http://archive.is/YwhFL>

⁴⁹ <http://ok.ru/group/52790918643940/album/53063513211108/562212661220> Archived - <https://archive.is/yOr9m>

⁵⁰ <https://youtu.be/dO8cBm2kqps>

⁵¹ <https://youtu.be/c4Pigqq8A74>

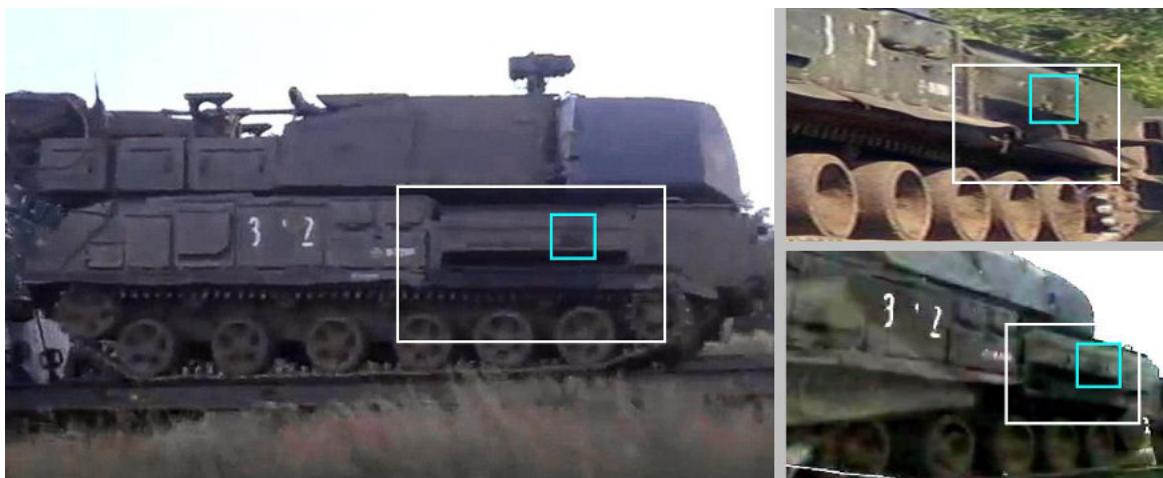
the three Buks shows that the font is the same for all four; however, only Buk 332 shows the same spacing and alignment of the 3x2. Even more, the two visible digits are a perfect match.



Comparison of the font and the spacing between the digits – Details of photos ^{52 53 54}

F: Shape and size of the oil stains and soot deposit at the exhaust

On all photos of the left side of Buk 3x2, strong dark patches can be seen on the side skirts below the exhaust. These patches are most likely caused by oil. Additionally, a striking soot or oil stain is located above the exhaust. Oil stains and soot deposits are certainly only a temporary feature because they can disappear by cleaning or repainting. However, a distinctive shape and position could also be caused by a special feature of the engine or the exhaust system, and a similar form at the same spot likely recurs, acting as indirect evidence of a persistent feature.



Buk 3x2 – Soot deposits or oil stains - Details of video and photos ^{55 56 57}

Soot and oil spots on Buk 312, Buk 322 and Buk 332:

⁵² http://vk.com/photo-56400949_306455856 Archived - <https://archive.is/WK4kQ>

⁵³ http://vk.com/photo34843743_336984208 Archived- <https://archive.is/vmeFR>

⁵⁴ http://vk.com/photo6517055_286122407 Archived - <https://archive.is/EhTcl>

⁵⁵ <https://youtu.be/c4Pigqg8A74>

⁵⁶ https://vk.com/wall-62387983_26806 Archived - <http://archive.is/bPiSs>

⁵⁷ https://youtu.be/hlM_QNs8i3w



Soot deposits or oil stains at Buk 312, Buk 322 and Buk 332 – Details of photos ^{58 59 60}

The oil stains on the side skirts are not recognizable in the photos of the three Bucs. However, some photos of Buk 332 show a soot deposit above the exhaust, approximately at the same position as that of of Buk 3x2.



Buk 332 – Soot above the exhaust on Buk 332– details of photos ^{61 62}

⁵⁸ http://vk.com/photo-56400949_306455856 Archived - <http://archive.is/cbccx>

⁵⁹ http://vk.com/photo34843743_336984208 Archived - <http://archive.is/vmeFR>

⁶⁰ http://vk.com/photo54417941_141494227 Archived - <http://archive.is/9glYg>

⁶¹ http://vk.com/photo54417941_141494227 Archived - <http://archive.is/9glYg>

⁶² <http://ok.ru/group/52790918643940/album/53063513211108/562212661220> Archived - <https://archive.is/yOr9m>

Overview of the compared individual features of Buk 3x2⁶³

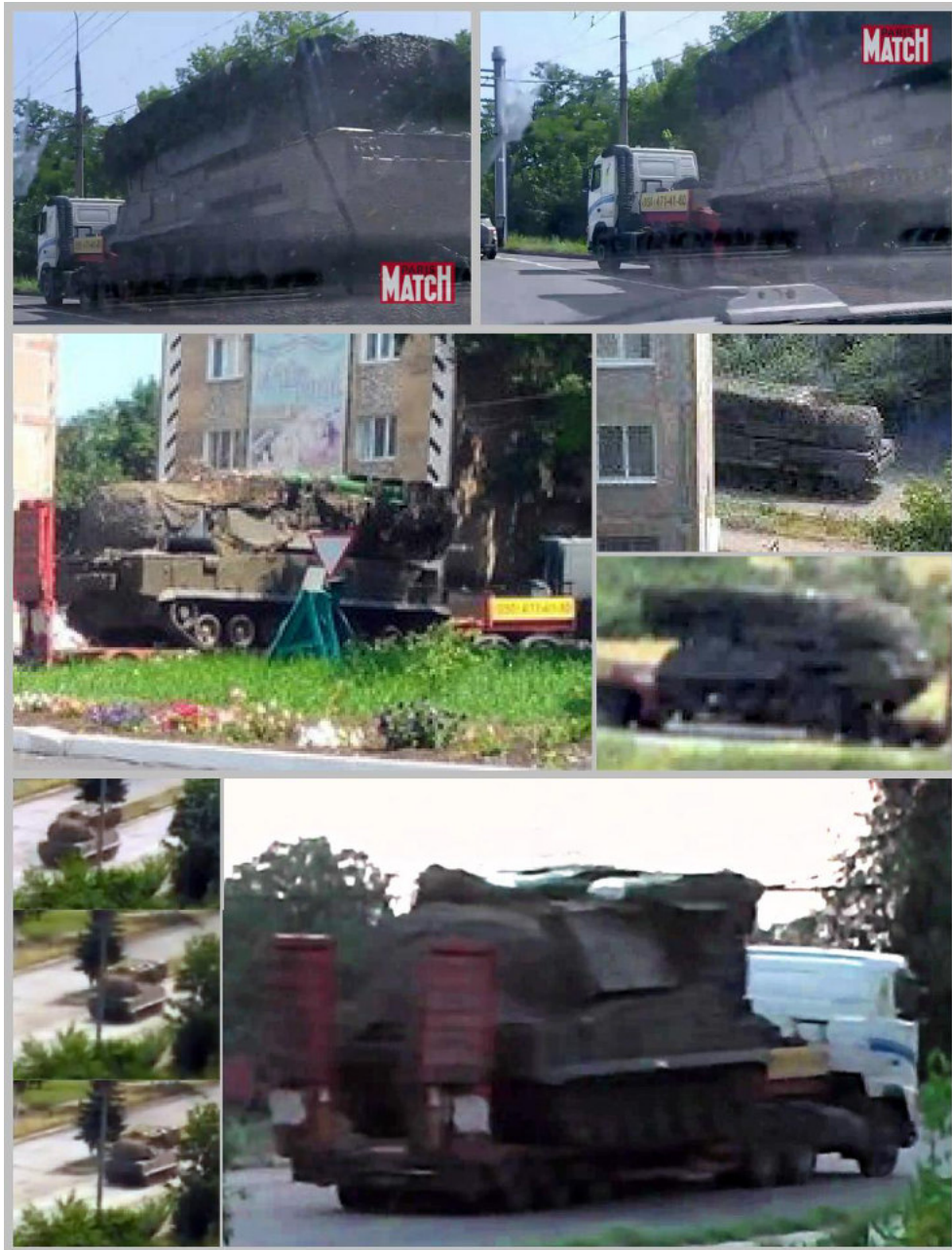
Feature of Buk 3x2	Buk 312	Buk 322	Buk 332
Fingerprint of side skirt	No match	No match	No match
Wheel concept left side	No match	Matches	Matches
Wheel concept right side	No match	No match	Matches
Dent on the side plate	No match	No match	Matches
Cable connection left side	No match	No match	Matches
Cable connection right side	No match	No match	Matches
White marks on side skirts	No match	No match	No match
Digits	No match	No match	Matches
Soot and oil stains	No match	No match	Partial matches

The above overview shows none of the examined Buks is a perfect match and shows all features of Buk 3x2. Buk 312 has no matching feature and Buk 322 has matching road wheels on one side. Buk 332 lacks two features and one feature is only a partial match. However, only considering the long-term features, Buk 332 is a perfect match to 3x2. The missing white markings were likely added after the last reference photo was taken. As discussed before, the reference photo used for Buk 332 was taken before the side skirt was damaged and repaired; therefore, it is unlikely that the side skirt shows the exact same "fingerprint" as Buk 3x2.

Comparison of Buk 3x2 with the Buk seen in eastern Ukraine on July 17-18, 2014

On 17 July 2014, a Buk was transported on a low loader from Donetsk to Snizhne in eastern Ukraine. The Buk was unloaded in Snizhne and moved on its own to an area south of the town. A few hours later, Malaysian Airlines Flight 17 was shot down with a missile launched by a Buk. The Dutch Safety Board concludes that the launch area of the missile responsible for the downing was south of Snizhne. On the following morning, a Buk was reportedly seen and filmed in Luhansk. This Buk was transported by the same low loader seen in the imagery of 17 July and was missing one missile.

⁶³ The statements in the overview refer only to the comparison result without evaluation. The validity of the comparison is judged in the text.

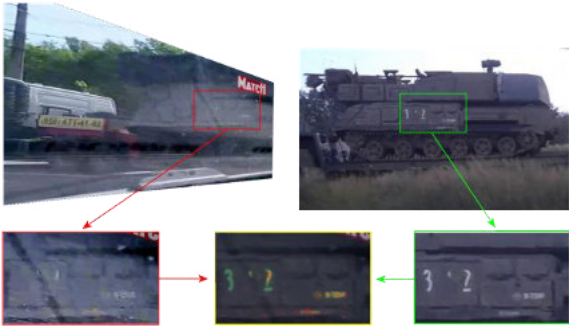


Previously known images of Buk in eastern Ukraine

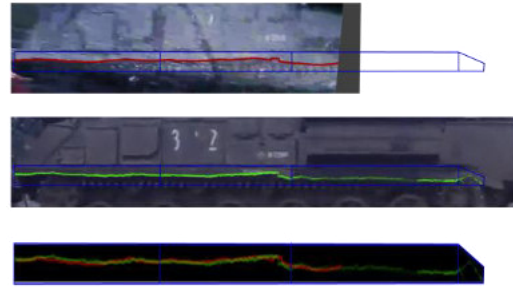
The movement of the Buk in eastern Ukraine on these two days was captured in four photographs and three video clips. Three of these photographs and a video show the left side of the Buk, while a photograph and two videos show the right side. The quality of these recordings or the recording angle is not appropriate to compare all seven⁶⁴ characteristics of Buk 3x2 mentioned above. However, some of the visible features can be checked.

The similarities between Buk 3x2 and the Buk in the separatist-controlled area on 17 and 18 July 2014 were already examined in the November 2014 Bellingcat investigation "Origin of the Separatists' Buk". The features examined in this report were the conformity of visible color residues with marks and digits of Buk 3x2, and the "wave form" of the side skirt (also known as its "fingerprint").

⁶⁴ In the research phase of this report, it became obvious that the missing railing can be at best only being considered as a short-term identification feature. Therefore, it is no longer mentioned in this report.



Buk – Comparison of the marks



Buk Side skirt "fingerprints"

The comparison of the side skirts showed a strong match, however, there is one area with a notable change in "wave form". It was found that this can be explained by an observable deformation of the side skirt.⁶⁵

The damaged and torn side skirt close to the exhaust on the left side of the Buk can be seen in the photos from Paris Match showing the Buk on the trailer on 17 July in Donetsk. In the same area above the fourth wheel, a similar damage pattern can be seen on Buk 3x2 in a video made in Russia.



Damage to the side skirt - Details of Video⁶⁶ and photo⁶⁷

A: Shape and arrangement of wheels

As explained in the preceding section, the road wheels of the Buk chassis can have two different types. There are two photos from 17 July available for the comparison of the 'Separatist' Buk with Russian Buk 3x2. The first picture shows the right side of the Buk on a low loader near a gas station in Torez. The second photo shows the left side of the Buk on the same low-loader in the outskirts of Donetsk

⁶⁵ <https://www.bellingcat.com/news/uk-and-europe/2015/01/17/new-images-of-the-mh17-buk-missile-launcher-in-ukraine-and-russia/>

⁶⁶ <https://www.youtube.com/watch?v=9JWUPGLqzZ4>

⁶⁷ <http://www.parismatch.com/Actu/International/EXCLU-MATCH-Un-camion-vole-pour-transporter-le-systeme-lance-missiles-577289>



Photo of a user from VKontakte - Torez⁶⁸



Photo from "Paris Match" - Donetsk, 17 July 2014⁶⁹

Neither image gives a clear view of the wheels. However, it is possible to state that at least some - and most likely all six - wheels are spoked on the left side. The low-resolution photo of the right side does not show all wheels. It is only possible to clearly identify the first road wheel as being from type spoke wheel. For the second wheel, no spokes are visible in the original resolution, which indicates a hollow wheel. However, the resolution is too low to reach a definite conclusion. It is not possible to identify the type of the other wheels. The third wheel is located in the shadow, and the other wheels cannot be assessed because they are hidden by other objects.



Road wheels left side - Original resolution - Detail of photo⁷⁰

The visible road wheels reflect the known arrangement of Buk 3x2. The left side only has spoked wheels, while there is one hollow wheel on the right side. Also, all Buks that have only hollow wheels can be excluded from being the 'Separatist' Buk.

B and C: Dent in the side panel and cables connected to the missile erector

The characteristics of the cable connections and the dent in the front panel are not visible in the available imagery from the 'Separatist' Buk. Therefore, a comparison of these features is not possible.

D: White marks on the side skirts

As mentioned in the last section, the white marks on both side skirts is a feature only visible on Buk 3x2 in the June convoy. Similar markings are also visible on the 'Separatist' Buk.

⁶⁸ https://vk.com/wall-5063972_387136?reply=387168 Archived - <http://archive.is/EQeY4>

⁶⁹ <https://www.bellingcat.com/news/uk-and-europe/2015/01/17/new-images-of-the-mh17-buk-missile-launcher-in-ukraine-and-russia/>

⁷⁰ https://vk.com/wall-5063972_387136?reply=387168 Archived - <http://archive.is/EQeY4>



White mark left side - right above the third wheel from the left- Details of Video ⁷¹ and photo ⁷². See the numbered wheels (1, 2, 3) for reference of the mark's location in the space between the 3rd and 4th wheels.



White mark right side- directly above the fourth wheel from the left - Details of videos ⁷³ ⁷⁴

The white marks on the Buk in the separatist-controlled area are in the exact same position as the white marks of Buk 3x2 in the Russian convoy in June 2014. The position of these transport markings is usually close to the sign marking the center of gravity. However, imagery of other Bucs with similar markings shows that these transport markings are not in the exact same locations.

E: Font and spacing of digits



Comparison of digits or fragments of digits for Buk xxx, Buk 3x2 and 332

⁷¹ <https://youtu.be/c4Pigqq8A74>

⁷² <http://www.parismatch.com/Actu/International/EXCLU-MATCH-Un-camion-vole-pour-transporter-le-systeme-lance-missiles-577289>

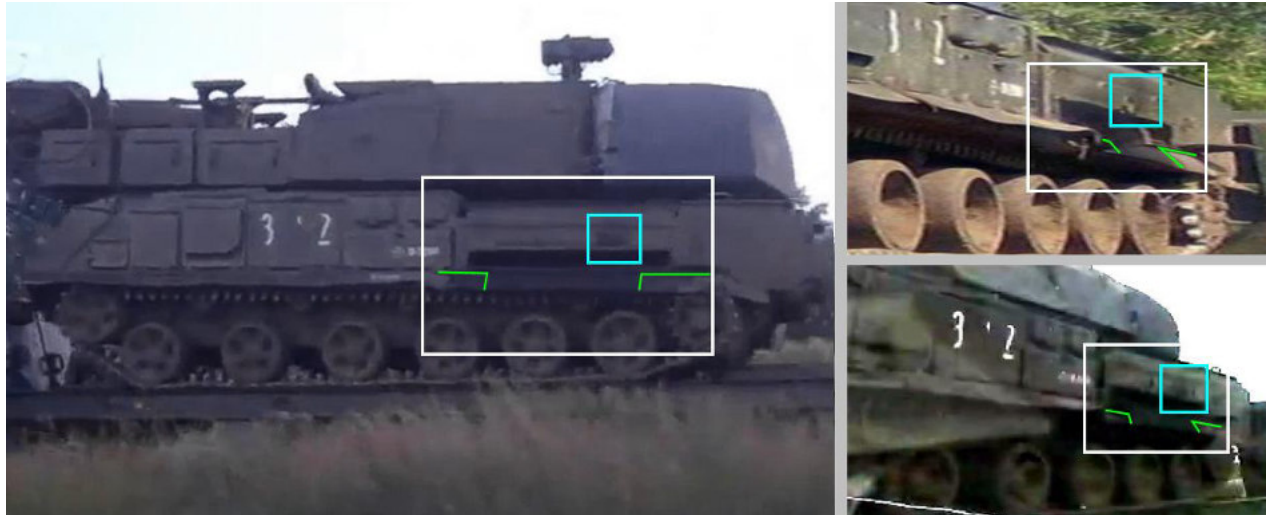
⁷³ <https://youtu.be/dO8cBm2kqps>

⁷⁴ <https://www.youtube.com/watch?v=L4HJmev5xg0>

A comparison between the partial digits of Buk 3x2 and the fragments of digits on the 'Separatist' Buk shows that the color, spacing, and visible fragments are congruent. Likewise, the same is true when comparing with the full digits of Buk 332.

F: Shape and size of the oil stains and soot deposit by the exhaust

Another feature of Buk 3x2 are the oil stains and soot deposits above and below the exhaust.



Soot deposits / oil stains on Buk 3x2 - Details of videos^{75 76} and photo⁷⁷

This characteristic oil stains or soot deposits are also found in two pictures and a video of Buk in separatist-controlled areas of eastern Ukraine.



Buk on 17 July 2014 in the separatist territory - soot deposits / oil stains - Photos^{78 79} and video⁸⁰

⁷⁵ <https://youtu.be/9JWUPGLqzZ4>

⁷⁶ https://youtu.be/hlM_QNs8i3w

⁷⁷ https://vk.com/wall-62387983_26806 Archived - <http://archive.is/bPiSs>

⁷⁸ <https://www.bellingcat.com/news/uk-and-europe/2015/01/17/new-images-of-the-mh17-buk-missile-launcher-in-ukraine-and-russia/>

⁷⁹ <https://twitter.com/GirkinGirkin/status/489884062577094656> Archived - <http://archive.is/eUnk9>

The soot spot above the exhaust is located at exactly the same position. Also visible is the large oil or soot deposits below the exhaust. These features are clearly visible in the Paris Match images, but the feature is large enough to even be visible in the low-resolution imagery of the Buk in eastern Ukraine.

Overview of the compared individual features of Buk 3x2⁸¹

A comparison of the 'Separatist' Buk and Russian Buk 3x2 shows that all of the verifiable features can be found on both vehicles. Moreover, no excluding features could be identified on the 'Separatist' Buk which would disqualify an identification as 3x2. Also, the comparison of the visible and identified features between the 'Separatist' Buk and the Buk 332 of the 53rd Anti-Aircraft Missile Brigade shows that both vehicles share numerous distinct features.

Feature of Buk 3x2	'Separatist' Buk	Buk 332
Fingerprint of side skirt	Matches	No match (in 2010)
Wheel scheme left side	Matches	Matches
Wheel scheme right side	Insofar as identifiable: Match	Matches
Dent on the side plate	Not verifiable	Matches
Cable connection left side	Not verifiable	Matches
Cable connection right side	Not verifiable	Matches
White marks on side skirts	Matches	No match (in winter 2012/2013)
Digits	Insofar as identifiable: Match	Matches
Soot and oil stains	Matches	Partial matches

⁸⁰ <https://www.youtube.com/watch?v=L04a3T4t7iw>

⁸¹ The statements in the overview refer only to the comparison result without evaluation. The validity of the comparison is judged in the text.

Discussion

This report examines characteristic individual features seen on Buk 3x2. This Buk was part of the Russian June 2014 convoy of the 53rd Anti-Aircraft Missile Brigade from Kursk to the Russian-Ukrainian border. It is possible to identify seven unique characteristics. This presence of these features on other Buk TELARs of the 53rd Anti-Aircraft Missile Brigade was also examined in this report.

A comparison of the seven characteristics on the Buk TELARs numbered 312, 322 and 332 of the 53rd Anti-Aircraft Missile Brigade reveals that only Buks 332 shares more than one characteristic with Buk 3x2. Four visible characteristics can be considered long-term or semi-permanent, one characteristic is partly visible in old imagery, and two of the characteristics are missing.

The shared characteristics—the second wheel on the right side being the only hollow wheel, the arrangement of the cable connections on both sides to the missile erector, the dent in the left front plate, the soot spot above the exhaust at the exact same position, and the exact match of the font and spacing of the digits—undoubtedly lead to the conclusion that Buk 332 of the 53rd Anti-Aircraft Missile Brigade and Buk 3x2 of the June convoy are one and the same vehicle. The two features that are different—the side skirt damage and railway transport marking on the side skirt—are features that could have been altered, intentionally and unintentionally, in the gap between available materials of Buk 3x2 and Buk 332. In the case of the railway transport marking, it is possible to say the marking was added at some point between the last photograph of it taken in the winter of 2012/2013 and the June 2014 convoy. In the case of the side skirt damage, a portion of the side skirt was repaired during gap of time between available materials.

Five of these seven characteristics could also be – at least partially – compared with the Buk photographed and filmed in the separatist-controlled areas of eastern Ukraine on 17 and 18 July 2014. In addition to the previously known features from the report "Origin of the Separatists 'Buk'", it was possible to identify further matches. The wheel type is – to the extent that it is comparable – identical. Both vehicles have the same white markings at the exact same position on the side skirts. Lastly, both share the soot spot above the exhaust at the exact same position, along with a sizeable deposit below the exhaust.

The visibly striking deposit below the exhaust also strengthens the identification of the Buk in the separatist-controlled territory, as a direct characteristic – in addition to the low loader – that is recognizable on multiple images and could be positively identified. Moreover, the analysis of the road wheels using other imagery shows that the spoke wheels identified on the 'Separatist'-Buk are no longer used by the Ukrainian unit based in the region. Therefore, it can be excluded that the 'Separatist'-Buk was captured from the Ukrainian units in eastern Ukraine. In addition, after an exhaustive search, the Bellingcat investigation team has not been able to locate materials depicting a single Ukrainian Buk with a "H-2200" railroad transport marking in 2014.

In sum, the survey of evidence leads to the following conclusions:

- The Buk filmed and photographed on 17 and 18 July in the separatist-controlled areas of eastern Ukraine did not originate from a Ukrainian Buk unit based in the region, in particular the 156th Anti-Aircraft Regiment.
- The 'Separatist' Buk and the Russian Buk 3x2 of the June 2014 convoy are one and the same vehicle.

- Buk 3x2 and Buk 332 of the Russian 53rd Anti-Aircraft Missile Brigade based in Kursk are one and the same vehicle.

Therefore, on 17 July 2014, the Russian Buk TELAR numbered 332 of the 53rd Anti-Aircraft Missile Brigade based in Kursk was filmed and photographed in eastern Ukraine. This specific Buk, previously identified as Buk 3x2, was filmed moving to the center of the launch area estimated by the Dutch Safety Board for the missile that downed MH17.

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Appendix

Appendix A – Technical support vehicles:⁸²

- 9V881M1 or 9V881 maintenance vehicle with trailer 9T456 carrying spare parts, tools and accessories;
- MTO-AG3-M1 or MTO-ATG-M1 maintenance workshop for trucks and tracked chassis;
- repair and maintenance vehicles MRTO-1 (9V883M1 or 9V883), MRTO-2 (9V884M1 or 9V884) and MRTO-3 (9V894M1 or 9V894);
- 9T243 transport vehicles for missiles with 9T318-1 rigging equipment packages or 9T229 transport vehicles with 9T318 packages;
- 9V930M-1, 9V930M-2 or 9V95M1 automated control and test mobile station for missiles;
- 9T458 missile repair vehicle;
- UKS-400V or UKS-400V-P4M unified compressor station;
- PES-100-T-230-Ch/400-A1RK1 or PES-100-T/400-AKR-1 mobile electric power station;
- 9T31M crane truck or an analog.

⁸² http://federalbook.ru/files/BEZOPASNOST/soderghanie/NB_2/NB2-2015-Goev.pdf
<http://www.niip.ru/upload/press/2009/statia15.pdf>
http://rbase.new-factoria.ru/missile/wobb/bukm1_2/bukm1_2.shtml
http://www.telenir.net/transport_i_aviacija/tehnika_i_vooruzhenie_1999_05_06/p6.php
http://www.niip.ru/index.php?option=com_content&view=article&id=16:-l-1-2r&catid=9:2011-07-06-06-33-50&Itemid=9

Appendix B - Structure of 53rd Anti-Aircraft Missile Brigade - Kursk

Brigade	combat weapons			combat weapons		
	1st Battalion	Crew	No.	1st Battalion - 1st Battery	Crew	No.
	Command post (CP) 9S470M1-2	6	100	Missile launcher with radar (TELAR) 9A310M1	4	111
	Snow drift radar (Kupol) 9S18M1-1	3	101	Missile launcher with radar (TELAR) 9A310M1	4	112
	BTR 80	3 + 7	993	Missile launcher with crane (TEL) 9A39M1	3	113
hardware	hardware system			combat weapons		
Mobile automated control and test station ACIS 9V930M-1	Car maintenance (MTO) 9V884M1	8	missiles	1st Battalion - 2th Battery		
	Workshop maintenance MTO-ATG-M1			Missile launcher with radar (TELAR) 9A310M1	4	121
	Car repair and maintenance (MRTO)			Missile launcher with radar (TELAR) 9A310M1	4	122
	Transport machines for Missiles (TM) 9T243			Missile launcher with crane (TEL) 9A39M1	3	123
	Transport machines for Missiles (TM) 9T243			combat weapons		
	Transport machines for Missiles (TM) 9T243			1st Battalion - 3rd Battery		
	Transport machines for Missiles (TM) 9T243			Missile launcher with radar (TELAR) 9A310M1	4	131
	Compressor station UKS - 400V-P4M;			Missile launcher with radar (TELAR) 9A310M1	4	132
	Mobile power PES - 100-T / 230-B / 400 A1RK1			Missile launcher with crane (TEL) 9A39M1	3	133
	combat weapons			combat weapons		
2th Battalion			2th Battalion - 1st Battery			
Command post (CP) 9S470M1-2	6	200	Missile launcher with radar (TELAR) 9A310M1	4	211	
Snow drift radar (Kupol) 9S18M1-1	3	201	Missile launcher with radar (TELAR) 9A310M1	4	212	
BTR 80	3 + 7		Missile launcher with crane (TEL) 9A39M1	3	213	
hardware system			combat weapons			
Car maintenance (MTO) 9V884M1	8	missiles	2th Battalion - 2th Battery			
Workshop maintenance MTO-ATG-M1			Missile launcher with radar (TELAR) 9A310M1	4	221	
Car repair and maintenance (MRTO)			Missile launcher with radar (TELAR) 9A310M1	4	222	
Transport machines for Missiles (TM) 9T243			Missile launcher with crane (TEL) 9A39M1	3	223	
Transport machines for Missiles (TM) 9T243			combat weapons			
Transport machines for Missiles (TM) 9T243			2th Battalion - 3rd Battery			
Transport machines for Missiles (TM) 9T243			Missile launcher with radar (TELAR) 9A310M1	4	231	
Compressor station UKS - 400V-P4M;			Missile launcher with radar (TELAR) 9A310M1	4	232	
Mobile power PES - 100-T / 230-B / 400 A1RK1			Missile launcher with crane (TEL) 9A39M1	3	233	
combat weapons			combat weapons			
3rd Battalion			3rd Battalion - 1st Battery			
Command post (CP) 9S470M1-2	6	300	Missile launcher with radar (TELAR) 9A310M1	4	311	
Snow drift radar (Kupol) 9S18M1-1	3	301	Missile launcher with radar (TELAR) 9A310M1	4	312	
BTR 80	3 + 7		Missile launcher with crane (TEL) 9A39M1	3	313	
hardware system			combat weapons			
Car maintenance (MTO) 9V884M1	8	missiles	3rd Battalion - 2th Battery			
Workshop maintenance MTO-ATG-M1			Missile launcher with radar (TELAR) 9A310M1	4	321	
Car repair and maintenance (MRTO)			Missile launcher with radar (TELAR) 9A310M1	4	322	
Transport machines for Missiles (TM) 9T243			Missile launcher with crane (TEL) 9A39M1	3	323	
Transport machines for Missiles (TM) 9T243			combat weapons			
Transport machines for Missiles (TM) 9T243			3rd Battalion - 3rd Battery			
Transport machines for Missiles (TM) 9T243			Missile launcher with radar (TELAR) 9A310M1	4	331	
Compressor station UKS - 400V-P4M;			Missile launcher with radar (TELAR) 9A310M1	4	332	
Mobile power PES - 100-T / 230-B / 400 A1RK1			Missile launcher with crane (TEL) 9A39M1	3	333	